



US009106542B2

(12) **United States Patent**
Venkateshwaran et al.

(10) **Patent No.:** **US 9,106,542 B2**
(45) **Date of Patent:** **Aug. 11, 2015**

(54) **SYSTEM AND METHOD FOR NETWORK TRAFFIC AGGREGATION AND ANALYSIS OF MOBILE DEVICES USING SOCKET WRAPPERS**

(75) Inventors: **Ramaswamy Venkateshwaran**, Fremont, CA (US); **David William Craig**, San Diego, CA (US); **Eugene V. Kolinko**, San Diego, CA (US); **Alexander Ivanov**, San Diego, CA (US)

(73) Assignee: **Qualcomm Innovation Center, Inc.**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 284 days.

(21) Appl. No.: **13/594,663**

(22) Filed: **Aug. 24, 2012**

(65) **Prior Publication Data**
US 2014/0059206 A1 Feb. 27, 2014

(51) **Int. Cl.**
G06F 15/173 (2006.01)
H04L 12/26 (2006.01)
H04L 29/06 (2006.01)
(52) **U.S. Cl.**
CPC **H04L 43/0894** (2013.01); **H04L 43/028** (2013.01); **H04L 43/0876** (2013.01); **H04L 43/0882** (2013.01); **H04L 69/162** (2013.01)

(58) **Field of Classification Search**
CPC H04L 43/0876; H04L 43/0882; H04L 169/162
USPC 709/224
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,424,489	B1 *	9/2008	Duffield et al.	1/1
7,783,750	B1 *	8/2010	Casey et al.	709/224
7,979,528	B2 *	7/2011	Eisenberg et al.	709/224
8,136,149	B2 *	3/2012	Freund	726/11
8,380,840	B2 *	2/2013	Vijay	709/224
8,555,295	B2 *	10/2013	Karino et al.	719/328
2002/0124074	A1 *	9/2002	Levy et al.	709/224
2007/0076606	A1 *	4/2007	Olesinski et al.	370/230
2009/0177567	A1 *	7/2009	McKerlich et al.	705/35
2010/0132024	A1 *	5/2010	Ben-Natan et al.	726/9
2011/0087779	A1 *	4/2011	Martin et al.	709/224
2011/0137960	A1 *	6/2011	Price et al.	707/812

(Continued)

OTHER PUBLICATIONS

"Network to Device Optimization," White Paper SEVEN Open Channel, Feb. 2011, pp. 15.

(Continued)

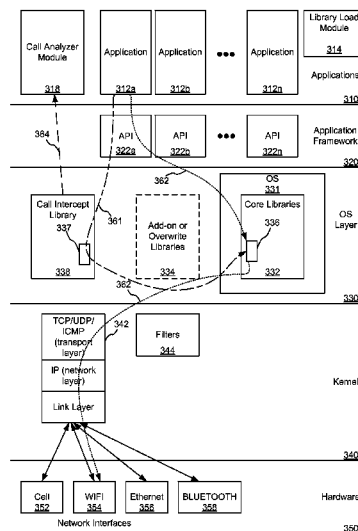
Primary Examiner — Lance L Barry

(74) Attorney, Agent, or Firm — Neugeboren O'Dowd PC

(57) **ABSTRACT**

This disclosure describes systems, methods, and apparatus for per-application network traffic monitoring by extending socket functionality to include socket wrappers able to identify network traffic volume, applications responsible for the traffic, the network being loaded, and distinguish between internal device traffic and external network traffic. Network traffic shaping can then be carried out by managing an offending application's traffic. A disclosed method includes loading a call intercept library prior to loading any core libraries of an operating system, calling a socket wrapper, calling a socket by way of functions of at least one of the core libraries, and receiving at least one data packet, from a responding application external to the communications device, at the socket. The method may also include trapping a call, to read the at least one data packet; and releasing the call to the socket so the data packet is read by the destination application.

23 Claims, 8 Drawing Sheets



(56)

References Cited

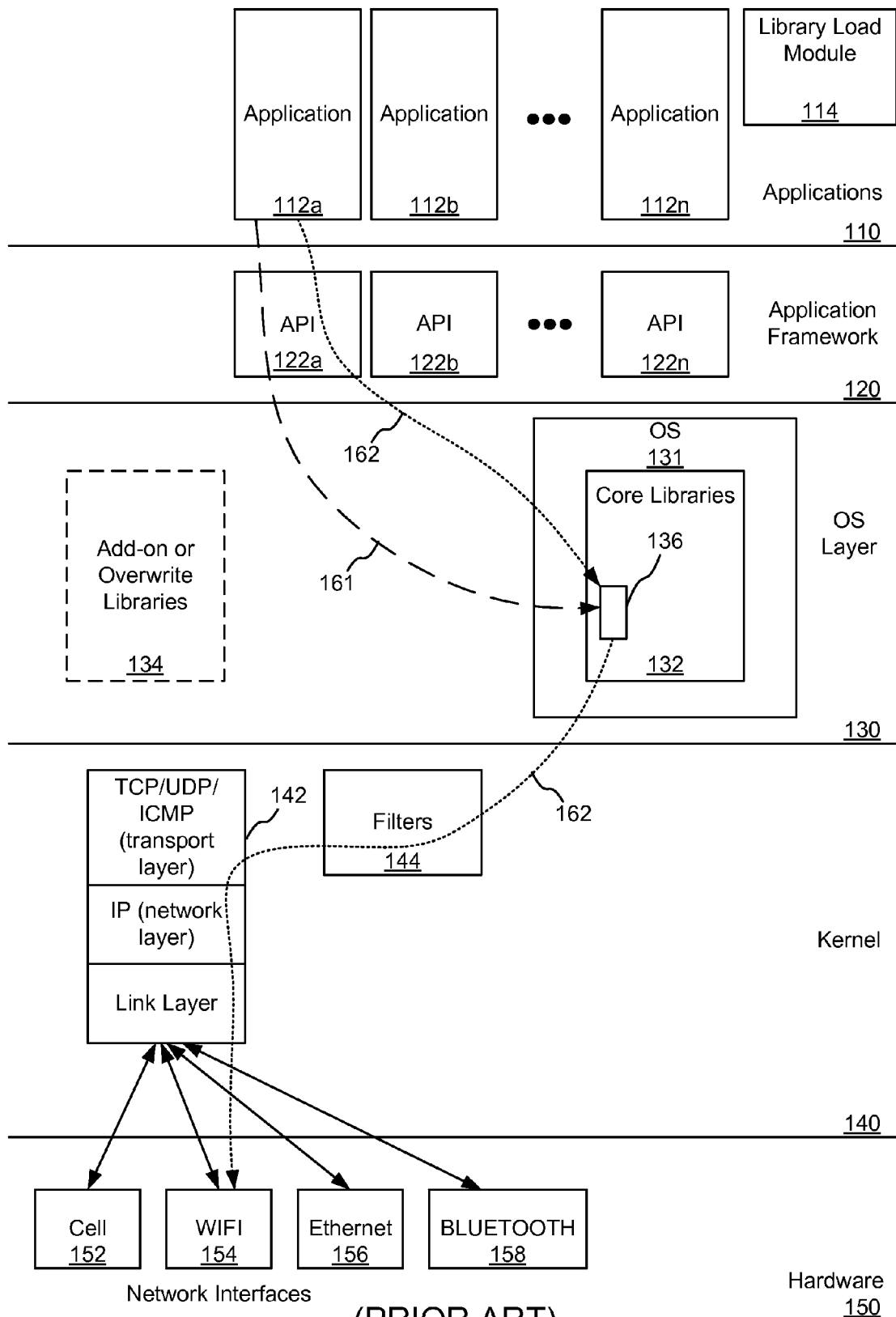
OTHER PUBLICATIONS

U.S. PATENT DOCUMENTS

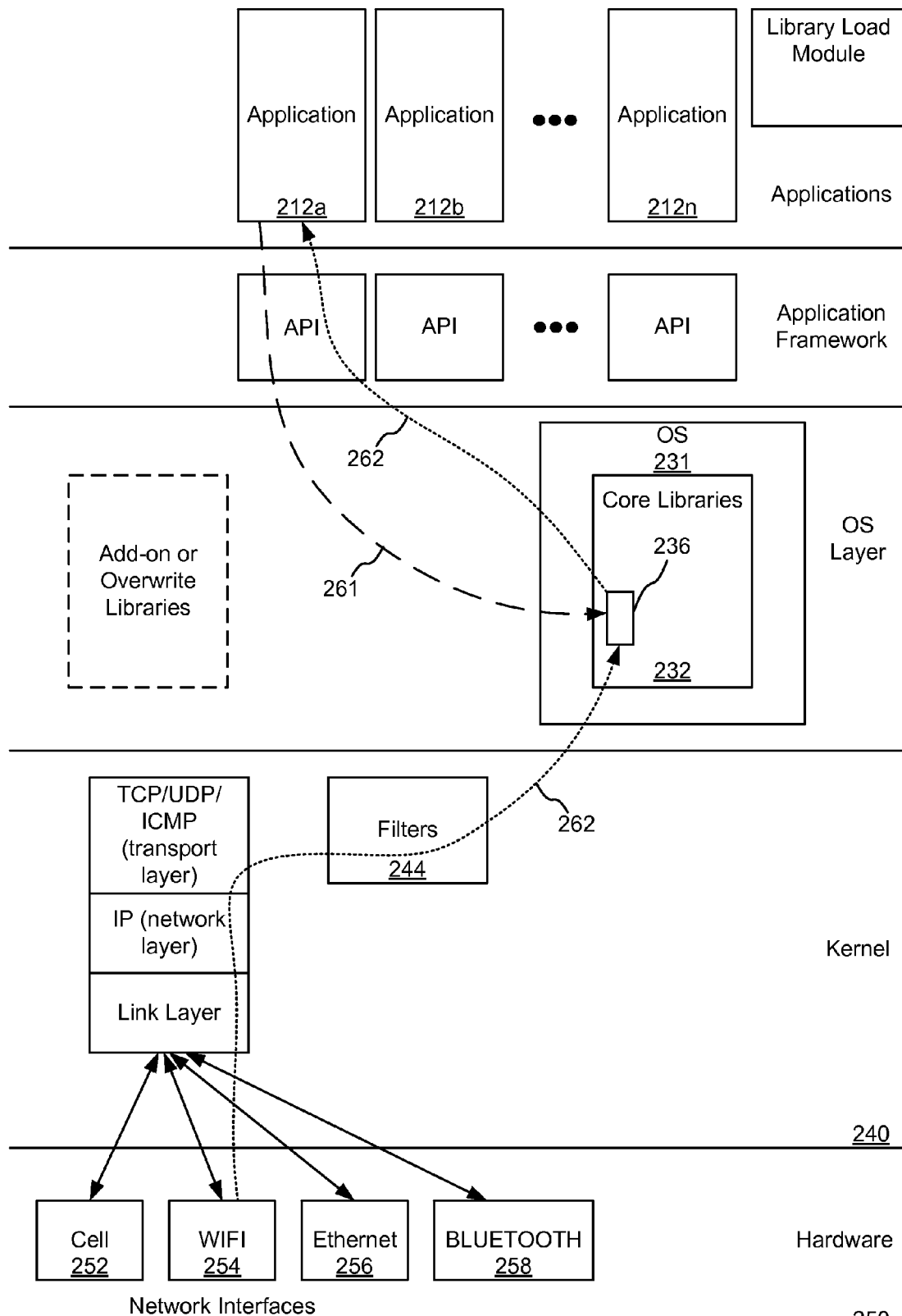
2012/0216063 A1* 8/2012 Ogata 713/323
2013/0291086 A1* 10/2013 Pontillo et al. 726/10
2014/0047535 A1* 2/2014 Parla et al. 726/15
2014/0059206 A1* 2/2014 Venkateshwaran et al. .. 709/224

Vandat, et al., “Scalability and Accuracy in a Large-Scale Network Emulator,” SIGOPS Oper. Syst. Rev. 36, SI (Dec. 2002), pp. 271-284.

* cited by examiner



(PRIOR ART)
FIGURE 1



(PRIOR ART)
FIGURE 2

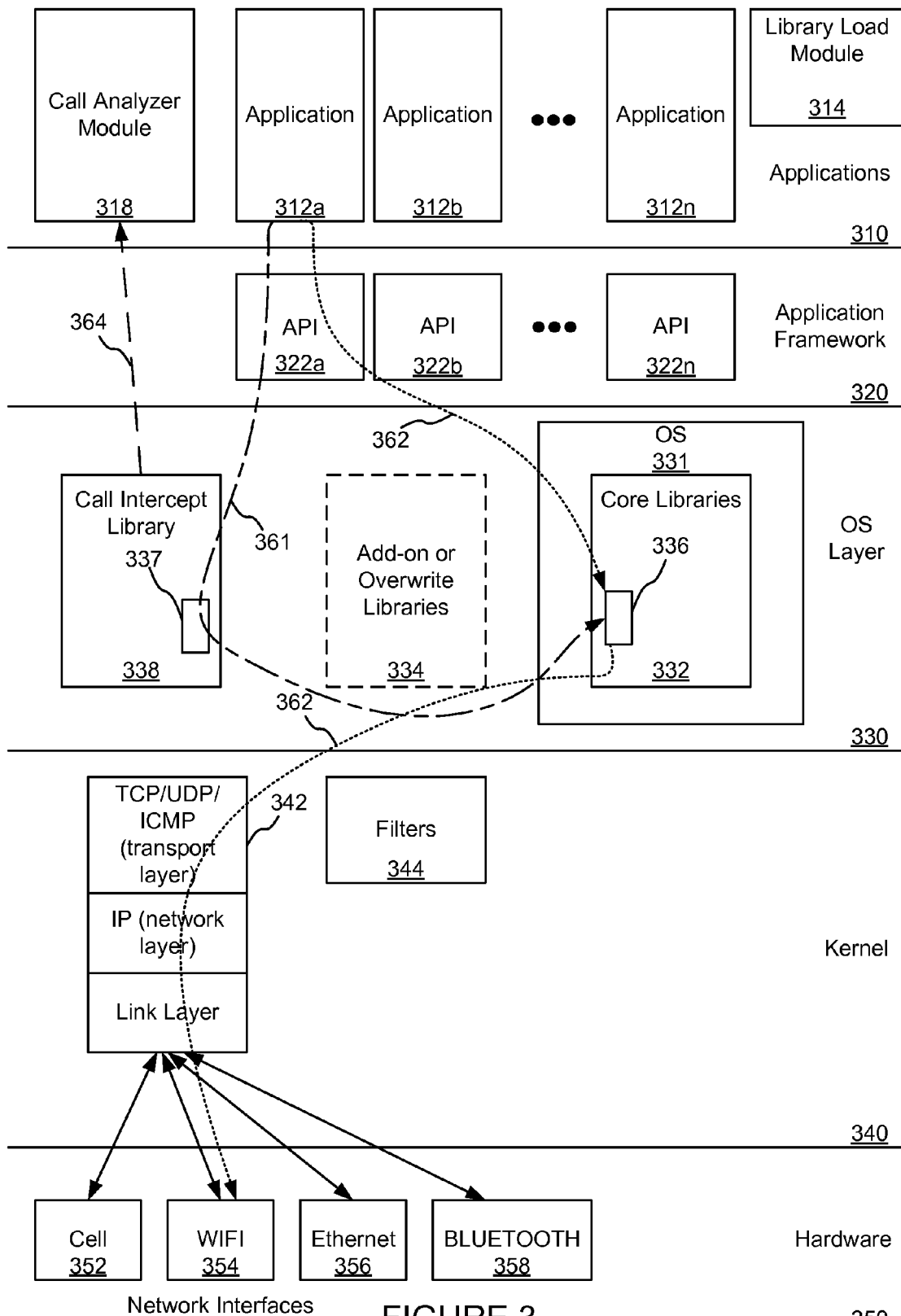


FIGURE 3

350

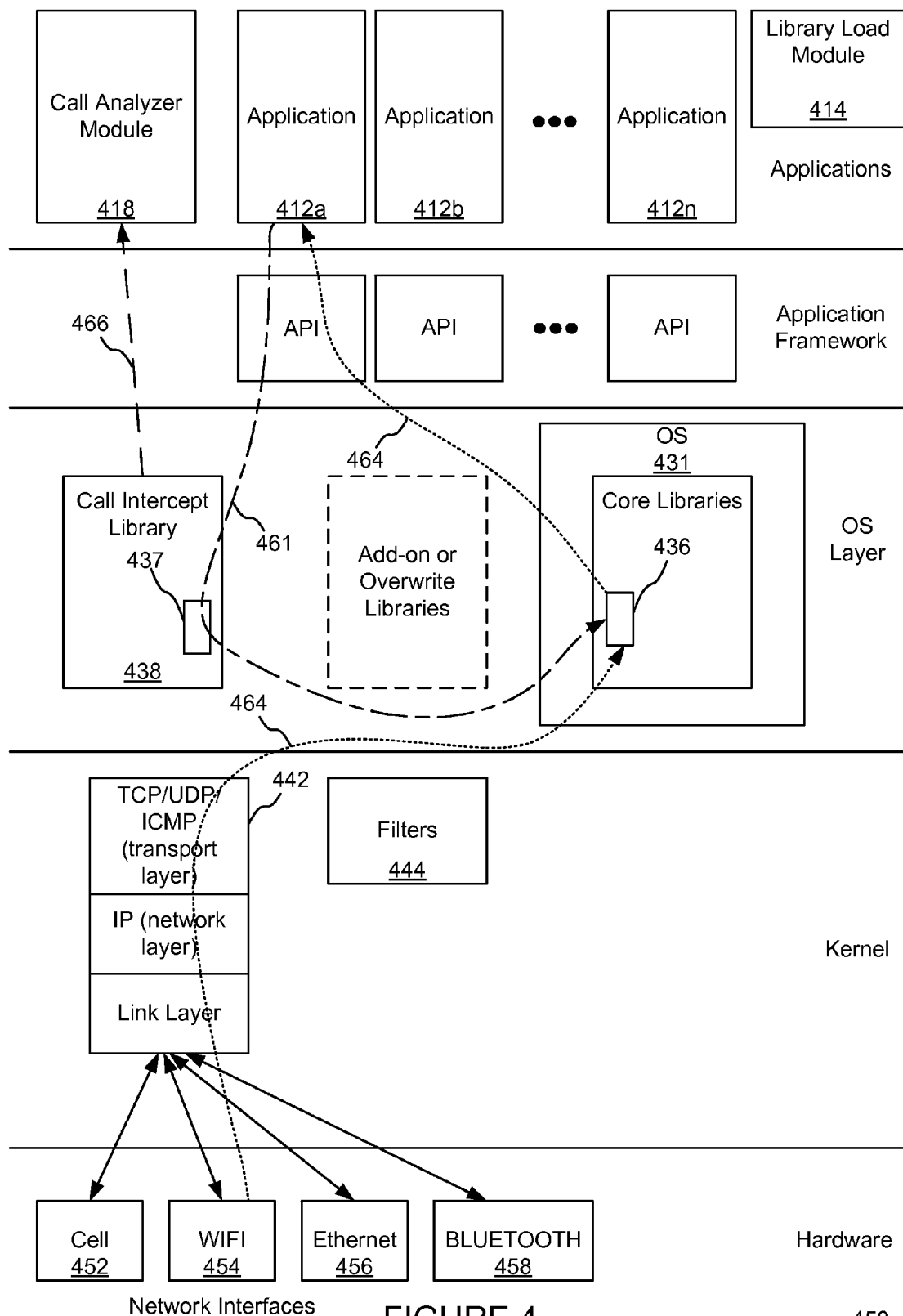


FIGURE 4

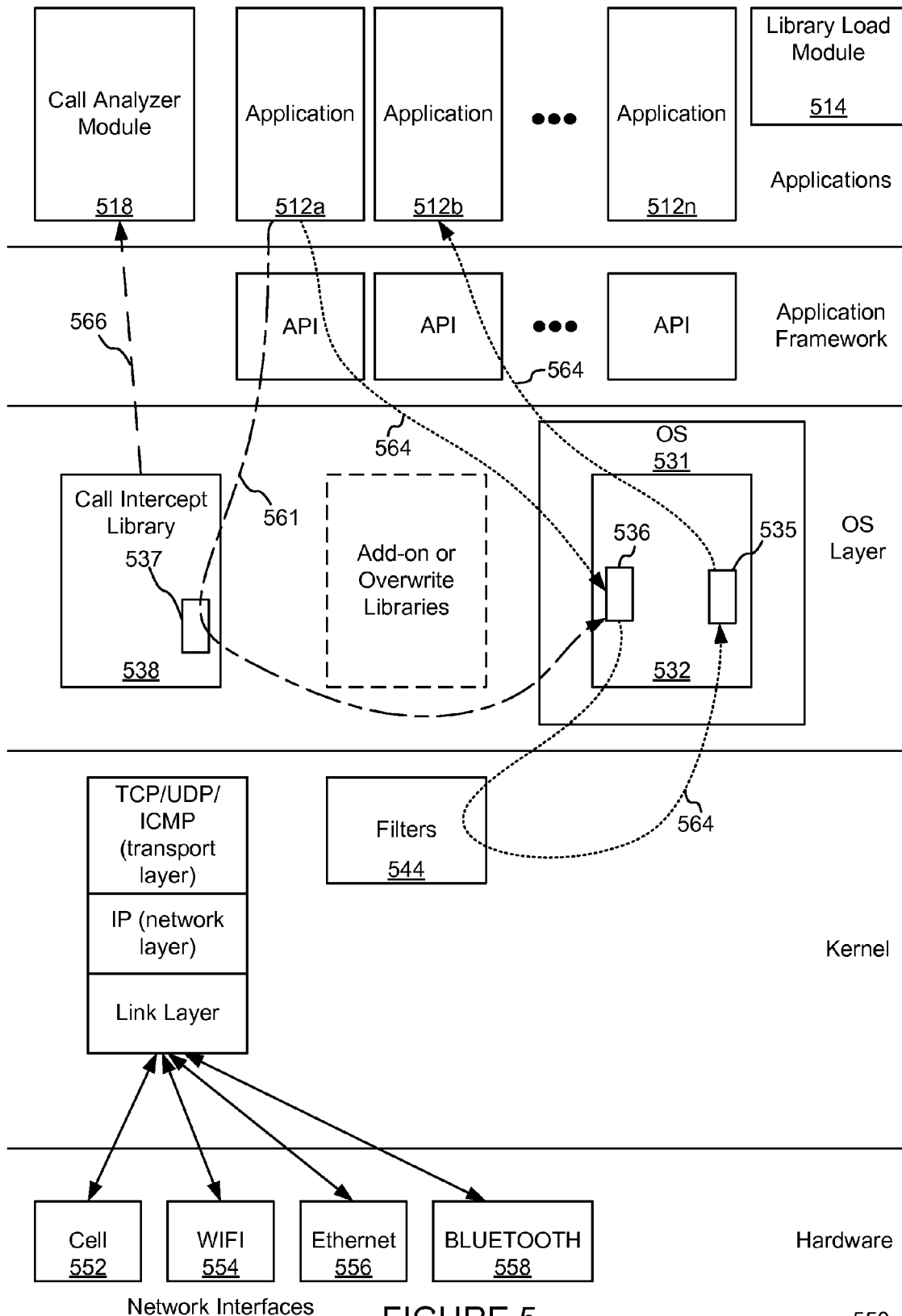


FIGURE 5

550

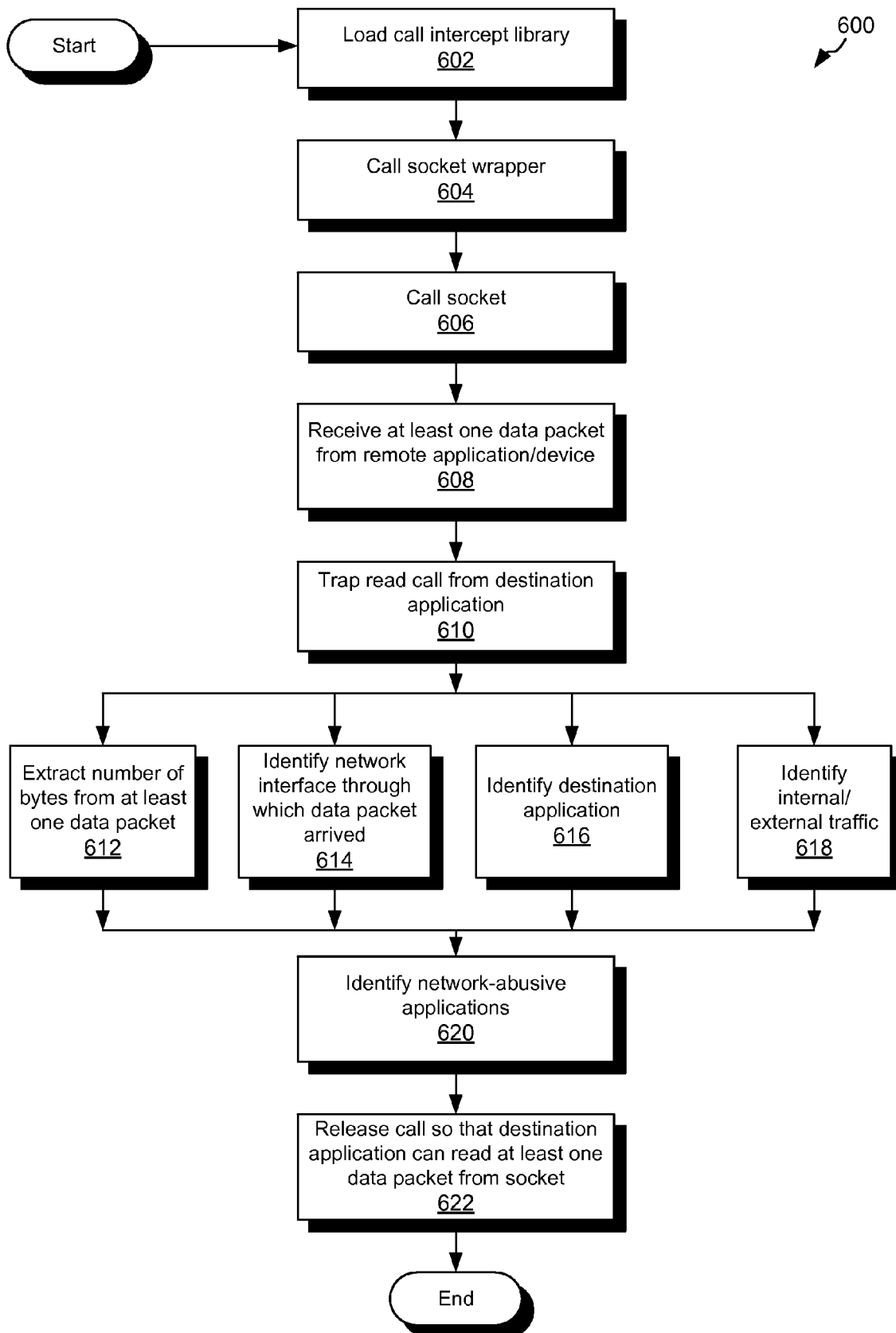


FIGURE 6

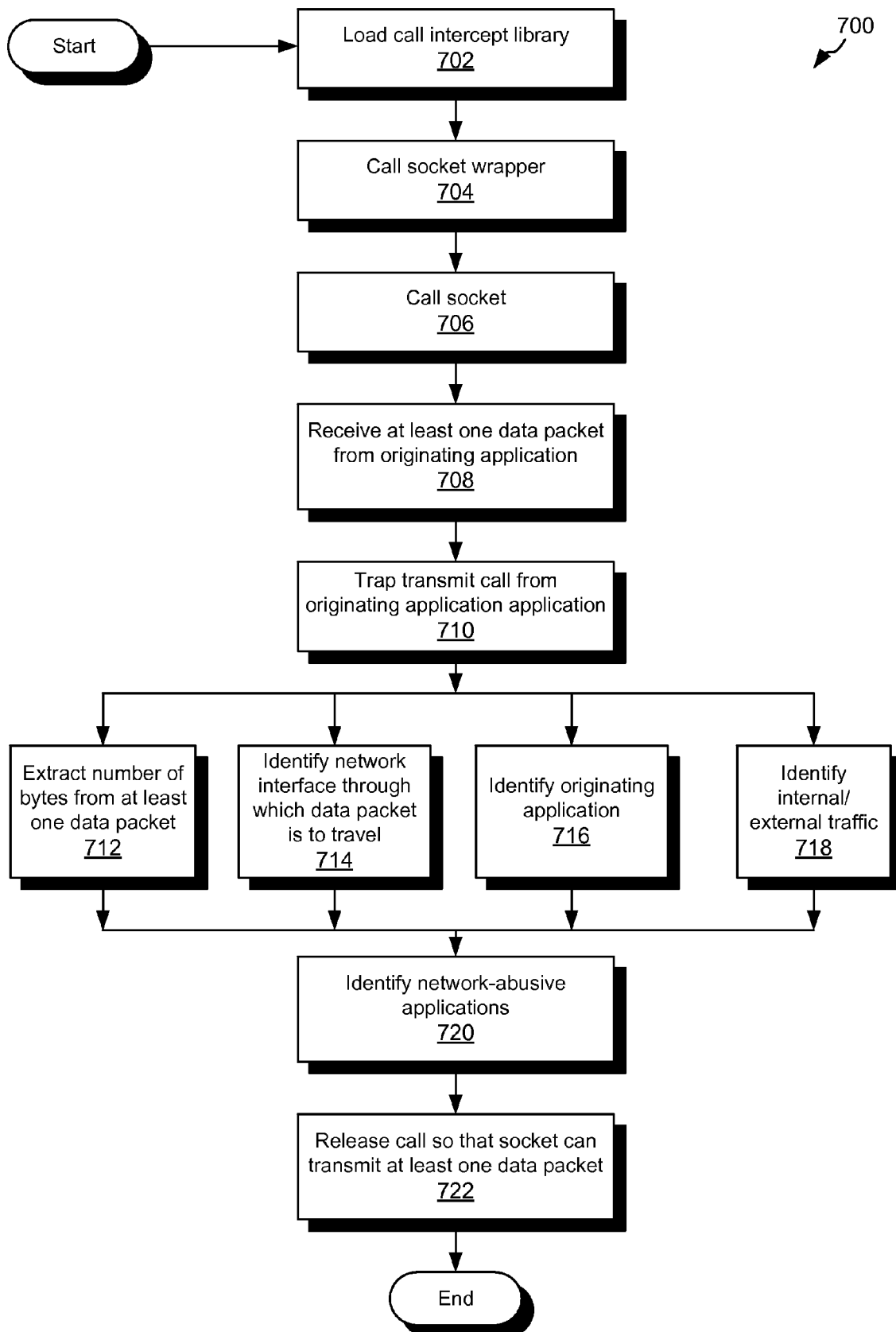


FIGURE 7

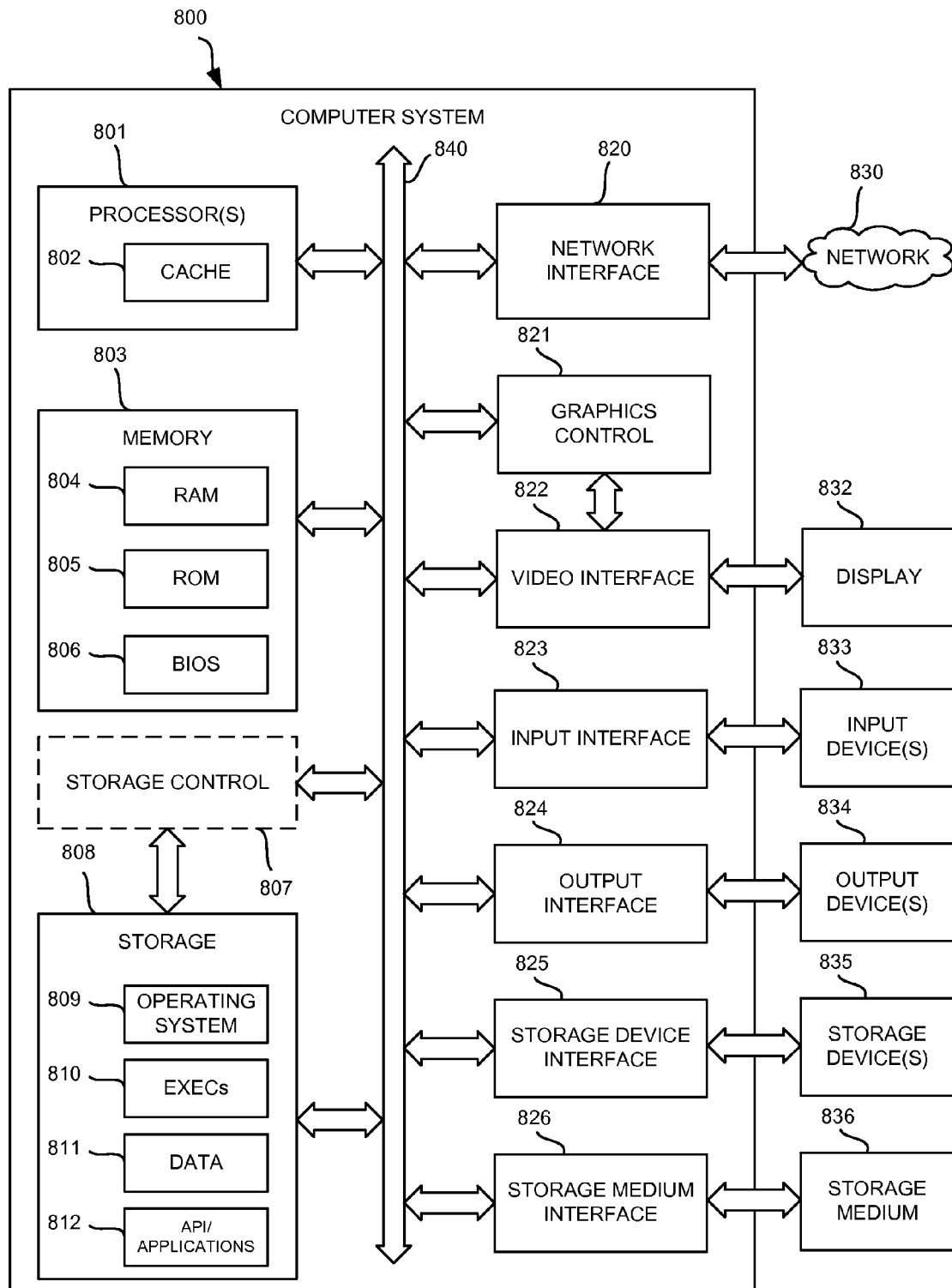


FIGURE 8

1

SYSTEM AND METHOD FOR NETWORK TRAFFIC AGGREGATION AND ANALYSIS OF MOBILE DEVICES USING SOCKET WRAPPERS

FIELD OF THE DISCLOSURE

The present disclosure relates generally to wireless mobile devices. In particular, but not by way of limitation, the present disclosure relates to systems, methods and apparatuses for monitoring network traffic on a per-application and per-network basis.

BACKGROUND

The widespread use of smartphones and cell-based WIFI hotspots has led to an explosion in signaling and data traffic on cellular networks. One way to manage this explosion is to identify and address applications that overuse the data network. There are current solutions that monitor network usage on a per-device basis, but these solutions suffer from the challenge of correlating whole-device usage to single application usages.

While there are some solutions that can monitor per-application network loading at the network layer, the data includes traffic that is internal to the phone (e.g., application-to-application traffic). Thus, their measurements of network traffic are skewed upwards by the inclusion of internal-device traffic and can create false positives when identifying network-abusive applications. These solutions also suffer from an inability to distinguish between applications that are responsible for downloaded network traffic (incoming traffic).

SUMMARY OF THE DISCLOSURE

Exemplary embodiments of the present invention that are shown in the drawings are summarized below. These and other embodiments are more fully described in the Detailed Description section. It is to be understood, however, that there is no intention to limit the invention to the forms described in this Summary of the Invention or in the Detailed Description. One skilled in the art can recognize that there are numerous modifications, equivalents and alternative constructions that fall within the spirit and scope of the invention as expressed in the claims.

Some aspects of the disclosure may be characterized as a communication apparatus for monitoring applications. The communication apparatus may comprise a network interface configured to receive a data packet from a network. The communication apparatus may further comprise a memory for storing a plurality of core libraries and a call intercept library. A further aspects of the communication apparatus can include a processor for running; a library load module configured to load the call intercept library and any of the plurality of core libraries, an application configured to read and process the data packet, a socket based in one of the plurality of core libraries, and a socket wrapper based in the call intercept library. The call intercept library can load before any of the plurality of core libraries. The socket can be configured to be called by the application using functionality of one of the plurality of core libraries after the network interface receives the data packet, and to receive the data packet from the network interface. The socket wrapper can be configured to trap a call from the application to the socket in order to read the data packet. The socket wrapper can also be configured to ascertain a number of bytes in the data packet. The socket wrap can further be configured to release the call to the socket

2

so that the application can read the data packet. The communication apparatus can further include a call analyzer module configured to determine a network traffic load attributable to the application based at least on the number of bytes in the data packet.

In some aspects, the socket wrapper may identify the network interface through which the data packet arrived. The call analyzer module may further determine whether the data packet originated internally or externally to the communication apparatus. The call analyzer module may also be configured to identify the destination application.

Other aspects of the disclosure may also be characterized as a method of monitoring network-abusing applications via methods at an OS layer of a communication device. The method may comprise loading a call intercept library prior to loading any core libraries of the OS, and calling a socket wrapper by way of functions of the call intercept library. The method may also include calling a socket by way of functions of at least one of the core libraries, and receiving at least one data packet from a responding application external to the communication device, at the socket. The method may also include trapping a call, from a destination application of the communications device, to read the at least one data packet. The method may additionally include extracting a number of bytes from the at least one data packet and releasing the call to the socket so that the at least one data packet is read by the destination application.

In some aspects, the method further includes identifying a network interface through which the at least one data packet traveled. Other aspects include determining whether the at least one data packet originated internally or externally to the communications device. In other aspects, the method identifies the destination application for the one or more data packets.

Other aspects of the disclosure can be characterized as a non-transitory, tangible computer readable storage medium, encoded with processor readable instructions to perform a method for identifying network-abusing applications on a communication apparatus. The method can include loading a call intercept library prior to loading any core libraries of the OS, and calling a socket wrapper by way of functions of the call intercept library. The method may also include calling a socket by way of functions of at least one of the core libraries. The method may further include trapping a call, from an originating application, to transmit at least one data packet, and extracting a number of bytes from the at least one data packet. Finally the method may release the call to the socket so as to allow the socket to release the at least one data packet for transmission.

Still other aspects of the disclosure can be characterized as a communication apparatus for monitoring network-abusing applications. The communication apparatus can include the following: a means for loading a call intercept library prior to loading any core libraries of the OS; a means for calling a socket wrapper by way of functions of the call intercept library; a means for calling a socket by way of functions of at least one of the core libraries; a means for trapping a call, from an originating application, to transmit at least one data packet; a means for extracting a number of bytes from the at least one data packet; a means for releasing the call to the socket so as to allow the socket to release the at least one data packet for transmission to another socket of the communication apparatus; and a means for identifying network abusing applications based on at least the number of bytes.

BRIEF DESCRIPTION OF THE DRAWINGS

Various objects and advantages and a more complete understanding of the present invention are apparent and more

3

readily appreciated by referring to the following detailed description and to the appended claims when taken in conjunction with the accompanying drawings:

FIG. 1 illustrates an abstraction of a software stack and associated hardware layer monitoring outbound network traffic at a kernel layer.

FIG. 2 illustrates an abstraction of a software stack and associated hardware layer monitoring inbound network traffic at a kernel layer.

FIG. 3 illustrates an abstraction of a software stack and associated hardware layer configured to monitor outbound network traffic at an OS layer.

FIG. 4 illustrates an abstraction of a software stack and associated hardware layer configured to monitor inbound network traffic at an OS layer.

FIG. 5 illustrates an embodiment of a software stack and associated hardware layer configured to monitor internal device traffic at an OS layer.

FIG. 6 illustrates a method for identifying network-abusive applications.

FIG. 7 illustrates a method for identifying network-abusive applications.

FIG. 8 shows a diagrammatic representation of one embodiment of a machine in the exemplary form of a computer system within which a set of instructions can execute for causing a device to perform or execute any one or more of the aspects and/or methodologies of the present disclosure.

DETAILED DESCRIPTION

The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any embodiment described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments.

A communication channel (or “channel”) can be a logical data connection that can be used to exchange data without storage of that data. A channel has two end points called sockets. Each socket is identified by an IP address (or a name in the case of local sockets), a family (e.g., Internet v4 or v6, a local domain, etc.), a port (or port number), and a transportation protocol (e.g., Transmission Control Protocol (TCP) or User Datagram Protocol (UDP)). The IP address can include a local address and a remote address, where the local address can be used to identify the source of outgoing data packets or the destination of incoming data packets. The remote address can be used to identify the destination of outgoing packets or the source of incoming packets. As examples of port numbers, a news server typically is assigned port number 119, a POP server is assigned port number 110, and an SMTP server is assigned port number 25. A socket typically enables communications between devices, but a pair of sockets can also enable communications between applications on the same device. Sockets distribute data packets to the correct application as those packets arrive through a channel.

The following discussion often discusses a pair of devices in communication with each other. In most situations where a first device communicates with a second device, one of the two devices initiates the communication and the other device responds to an initiation action. As such, devices that communicate with each other in this disclosure will be described in terms of an initiating device and a responding device. It will be recognized that either device can be the initiating or responding device and that these roles can switch over time. In some cases, the initiating device may be a client and the responding device may be a host in a client-host relationship. For instance, a user device such as a smartphone can be the client (initiating device) and a remote web server can be the

4

host (responding device). In others, the initiating device may be a peer device and the responding device may be a peer device, and these roles can switch depending on the circumstances. For instance, a user device such as a smartphone can be a first peer (initiating device) and another user device such as a tablet computer can be a second peer (responding device), or vice versa. These examples are illustrative only, and one of skill in the art will recognize that other variations of initiating and responding devices are also possible. In some cases, communication may be one way and thus the responding device can be replaced by a “receiving device” (e.g., where a server initiates an unrequested download to a client). As such, the responding devices described herein can be considered synonymous with receiving devices.

In some embodiments, this disclosure is related to monitoring network usage for a mobile computing device, such as a smartphone, tablet computer, or ultrabook. In particular, some embodiments describe systems, methods, and apparatus for monitoring network traffic on a per-application basis and with identification of the networks that a given application is using (e.g., Ethernet, WIFI, cellular, 3G, 4G, etc.). This enables identification of applications that put the greatest burden on a network, the network being burdened by certain applications, and the degree of the burden. Accurate identifications are also made since some embodiments of this disclosure distinguish internal device traffic from network traffic thus avoiding false positives which would otherwise cause overestimates of network traffic.

Current solutions have tried to work within a typical framework as illustrated by the FIG. 1 abstraction of a software stack and associated hardware layer 150 (e.g., the ANDROID stack). The stack includes an applications layer 110 having a plurality of applications 112a, 112b, . . . , 112n and a library load module 114, an application framework layer 120 having a plurality of application programming interfaces (API's) 122a, 122b, . . . , 122n, an operating system (OS) layer 130 including core libraries 132 and add-on or overwrite libraries 134, and a kernel layer 140 including a network stack 142, filters 144, and various driver modules 146 (e.g., display, keypad, camera, WIFI, memory, audio). The hardware layer 150 includes, among other components, a plurality of network interfaces 152, 154, 156, 158 (only four of many possible network interfaces are illustrated). It should be understood that the illustrated software stack illustrated in FIG. 1 as well as those illustrated in FIGS. 2-5 are not limited to the layers and features that are illustrated, as some layers and features may not be illustrated or described in order to simplify this disclosure. For instance, driver modules, a common feature of the kernel layer 140, are not illustrated or discussed.

When an application, such as an originating application 112a, seeks to communicate with a remote application on a responding device (not illustrated) (e.g., a website on a remote web server), the originating application 112a makes a call 161 to the OS 131 to “send” one or more data packets 162. In other words, the application calls the socket 136, and the socket 136 is created via functionality of the core libraries 132, where the core libraries 132 describe programming methods including those for creating and using sockets. A set of network interface selection rules or a routing table determines which of a plurality of network interfaces 152, 154, 156, 158 will be used to establish the communication to the remote application. For instance, the set of network interface selection rules may determine that the socket 136 is to use the WIFI network interface 154.

The OS 131 assigns the socket 136, among other things, a local socket address (identifying the source of the communication by IP address and port number) and a remote socket

address (identifying the destination of the communication by IP address and port number). Each network assigns an IP address to the corresponding network interface **152, 154, 156, 158**, and the OS **131** can assign one of these IP addresses to the socket **136** once the OS **131** decides which network interface **152, 154, 156, 158** the socket **136** is to use (in this case the WIFI network interface **154**). This IP address can be part of the local socket address, and identifies not only the socket **136**, but also the network interface **152, 154, 156, 158** to be used for transmission of the one or more data packets **162**. The OS **131** can assign the socket **136** an arbitrary port number selected from a list of available port numbers on the initiating device. The port number in conjunction with the IP address and possibly other parameters identifies the socket **136**.

If a transport protocol for the socket **136** is TCP, then data packets are streamed and the OS **131** can assign the local socket address when a connection with the responding device is established. If the transport protocol is UDP, then datagrams are sent to the responding device, and the OS **131** can assign the local socket address to the socket **136** when the first datagram is sent.

The socket **136** can also be assigned a remote socket address including an IP address of the responding device and a port number for an application running on the responding device. The remote socket address may be extracted from a memory of the initiating device, or in the alternative, a DNS query can be performed to retrieve an IP address and port number.

Once a connection has been made in TCP, the responding device can send data packets back to the socket **136** using the local socket address appended to one or more data packets to direct responses back to the initiating device. In the case of UDP, the responding device can extract the local socket address from the one or more data packets **162** and use the local socket address to respond to the socket **136**.

While data packets pass from the socket **136** to the responding device, filters **144** can measure a number of bytes in the one or more data packets **162**. Via the filters **144** of the kernel layer **140**, the OS **131** also monitors metadata associated with the socket **136** including a process ID of the process that owns the socket **136** and a socket descriptor assigned to the socket **136**. When the one or more data packets **162** are accessed by the filters **144**, the filters **144** access the metadata using the socket descriptor as a key to lookup the data. In this fashion, the filters **144** have access to the process ID and can therefore identify which application **112a, 112b, . . . , 112n** sent the one or more data packets **162** (e.g., the originating application **112a**). The filters **144** can also identify which network interface **152, 154, 156, 158** the one or more data packets **162** are traveling through (e.g., the WIFI network interface **154**).

The local socket address includes an IP address which identifies which of the network interfaces **152, 154, 156, 158** is being used for the communication (e.g., the WIFI network interface **154**). By identifying the amount of traffic associated with the socket **136** as well as which of the applications **112a, 112b, . . . , 112n** is responsible for the traffic and which of the network interfaces **152, 154, 156, 158** is being used, applications **112a, 112b, . . . , 112n** that excessively use the network for outbound traffic can be identified (hereinafter referred to as “network-abusing applications”).

However, the filters **144** are not effective to identify network-abusing applications when traffic is inbound. Inbound traffic, or downloading, is the more common use of the network by an initiating device, and thus the more important for identifying network-abusing applications. The reason that the

filters **144** are ineffective to determine network download traffic on a per-application basis is illustrated in FIG. 2.

FIG. 2 illustrates a software stack and associated hardware layer **250** receiving one or more inbound data packets **262** as commonly utilized in the art. Here, the responding device directs one or more inbound data packets **262** to the local socket address of the initiating device and an originating (or recipient) application **212a**. For example, the local socket address can include an IP address and port number assigned to the socket **236**. The socket **236** receives the one or more inbound data packets **262** from the responding device and makes these available to the originating application **212a** in response to a “read” call **261**.

The kernel layer **240** can include a mapping of the IP address and port number assigned to the socket **236** that identifies the originating **212a** application. However, the IP address and port number do not indicate to the filters **244** which application is the originating application **212a**. In this description the remote device sending the one or more inbound data packets **262** will be referred to as the responding device (e.g., where a remote web server responds to a client request), and the local device receiving the one or more inbound data packets **262** will be referred to as the initiating device (e.g., a client that made a request to a remote web server). However, one of skill in the art will recognize that the so-called responding device could also be an initiating device and the so-called initiating device could be a responding device or merely a receiving device.

Filters **244** can count a number of bytes in the one or more inbound packets **262** and identify which of a plurality of network interfaces **252, 254, 256, 258** is being used (e.g., the WIFI network interface **254**). For instance, where the communication was established via the WIFI network interface **254**, traffic from the responding device will enter the initiating device via the WIFI network interface **254**. However, since the filters **244** exist in the kernel layer **240** and are processed by the kernel, they have access only to the metadata in the one or more inbound data packets **262**, which only includes an IP address and port number of the socket **236**, not the mapping that identifies the originating application **212a** associated with the socket **236**. In other words, the filters **244** do not have access to the process ID or user ID of the originating application **212a**. The mapping is maintained in the OS **231** and is not easily accessible when the filters **244** are processed by the kernel. Filters **244** are thus ineffective at identifying network-abusing applications for inbound traffic (downloads).

To more accurately assess network traffic, and to do so on a per-application basis for both inbound and outbound traffic, this disclosure enables network traffic monitoring at an OS layer rather than by filters in a kernel layer. Various embodiments of such network traffic monitoring systems, methods, and apparatus are illustrated in FIGS. 3-6.

FIG. 3 illustrates one embodiment of a software stack and hardware layer **350** configured to monitor network traffic at an OS layer **330** rather than at a kernel layer **340**. Traditionally, an originating application **312a** (e.g., a web browser) makes a call **361** to the operating system (OS) **331**, that, via functionality of core libraries **332**, creates a socket **336** as a first endpoint of communication with a socket of a responding device (not illustrated), such as a web server hosting a webpage. However, the functionality of the socket **336** can be extended by functionality of a socket wrapper **337** as provided by a call intercept library **338**. The call intercept library **338** can be scripted to load before the core libraries **332** such that the socket wrapper **337** traps the call **361** and analyzes the one or more data packets **362** at the socket **336**. In one

embodiment, a library load module 314 can load the call intercept library 338 and the core libraries 332 into a memory such that the call intercept library 338 is loaded first. The call 361 is released to the socket 336 and the one or more data packets 362 are passed to a network stack 342 of the kernel layer 340 for transmission. Despite the socket wrapper 337 trapping the call 361, in a preferred embodiment, the socket wrapper 337 has little or no impact on the user experience. For instance, there may be no noticeable delay, interruption, or other degradation to the user experience.

An applications layer 310 includes a plurality of applications 312a, 312b, . . . , 312n (where n is a positive integer representing a number of applications) along with a call analyzer module 318. The plurality of applications 312a, 312b, . . . , 312n are often written in Java and can include applications such as an e-mail client, an SMS program, a calendar, maps, a browser, contacts, a phone, and many others. The call analyzer module 318 uses information 364 provided by the call intercept library 338 to determine a number of bytes in each of the one or more data packets 362 as well as to identify the application sending/receiving each packet (e.g., 312a). The call analyzer module 318 can also determine which network interface 352, 354, 356, 358 is being (or will be) used to transmit each of the one or more data packets 362. Through this analysis, the call analyzer module 318 can identify network-abusing applications, and determine what, if any, actions to take to improve network usage (e.g., throttling network access for network-abusing applications).

The application framework layer 320 can include a plurality of application programming interfaces (APIs) 322a, 322b, . . . , 322n, at least one for each application in the plurality of applications 312a, 312b, . . . , 312n. The application framework layer 320 can act as an interface between the applications layer 310 and the OS layer 330. Each one of the plurality of applications 312a, 312b, . . . , 312n can have one or more corresponding APIs 322a, 322b, . . . , 322n used to interact with the OS layer 330. Developers can use previously developed APIs 322a, 322b, . . . , 322n, or components thereof, to construct new or modified APIs.

The OS layer 330 includes an OS 331 having core libraries 332 (e.g., System C, Media, Surface Manager, LibWebCore, SGL, 3D, FreeType, and SQLite, to name a few). Core libraries 332 can function to play audio files, render graphics, and enable web browsing, to name just a few exemplary functions. The functionality of these core libraries 332 can be extended or replaced via optional add-on or overwrite libraries 334 (e.g., a graphics library or phonebook library) created by applications developers ("developers") via the applications framework layer 320. The OS 331 can, in one embodiment, be an ANDROID operating system.

The originating application 312a can make a call 361 to transmit one or more data packets 362, and this call 361 can create the socket 336 via functionality of one or more of the plurality of core libraries 332. Along with creating the socket 336, functionality of one or more of the plurality of core libraries 332 assigns a source IP address to the socket 336, where the source IP address is the local IP address (generally not publicly routable) that a network assigned to the WIFI network interface 354 (or whichever network interface 352, 354, 356, 368 the OS 331 decides to send the one or more data packets 362 through). For instance, where it is determined that the one or more data packets 362 will traverse the WIFI network interface 354, the source IP address for the socket 336 can be the local IP address that the WIFI network assigned to the WIFI network interface 354. In some cases a public IP address can be assigned to one of the network

interfaces 352, 354, 356, 358, such as when a cellular network operator assigns a public IP address to a device on its cellular interface.

The core libraries 332 can provide methods or functionality to generate at least one socket 336 when one of the applications 312a, 312b, . . . , 312n seeks to communicate with a responding device (not illustrated) or with another one of the applications 312a, 312b, . . . , 312n within the initiating device. When the originating application 312a (e.g., a social media web-based application), seeks to communicate with a responding device (e.g., a remote web server), and a remote application of the responding device (e.g., the social media website operating on the remote web server), the originating application 312a can make a call 361 to the OS 331 requesting transmission of the one or more data packets 362.

The socket wrapper 337 can trap the call 361 before the socket 336 passes the one or more data packets 362 to the network stack 342 and can analyze the one or more data packets 362 to obtain information related to one or more of the following: (1) a number of bytes per data packet; (2) which of the one or more applications 312a, 312b, . . . , 312n is the source of the one or more data packets 362 (via a user ID and/or process ID); (3) which network interface 352, 354, 356, 358 will be used to transmit the one or more data packets 362 (via the source IP address of the socket 336); and (4) whether the one or more data packets 362 are destined for a responding device or another application 312b, . . . , 312n internal to the initiating device (via metadata indicating a type of socket address, type of socket, or socket family) (this situation is discussed further with reference to FIG. 5). This functionality is an extension of the core libraries 332 functionality that replaces the functionality of the socket 336 with that of a call intercept library 338.

When the one or more data packets 362 are passed from the originating application 312a to the socket 336, the OS 331 can switch contexts to that of the originating application 312a, which owns the socket 336—a context that the socket wrapper 337 also runs in. The socket wrapper 337 can trap a call 361 to the socket 336 to transmit the one or more data packets 362. Having trapped the call 361, and running in the context of the originating application 312a, the socket wrapper 337 can access metadata of the originating application 312a, which includes a process ID and/or user ID that identify the originating application 312a. In some cases, a database of the OS 331 can be used to lookup a name of the originating application 312a—the application that owns the context in which the socket 336 and socket wrapper 337 operate in—based on the process ID and/or user ID.

The OS 331 assigns a socket descriptor to the socket 336 when the socket 336 is created. The kernel maintains a mapping of the socket descriptor to socket metadata as well as methods enabling the socket wrapper 337 to query the kernel for the socket metadata thus giving the socket wrapper 337 access to information such as the socket descriptor, local and remote IP addresses, and socket family, to name a few.

The functionality of the socket wrapper 337 can be enabled by scripting the call intercept library 338 to have a priority in loading over the core libraries 332. In other words, the OS layer 330 can load the call intercept library 338 before it loads the core libraries 332, thus enabling the socket wrapper 337 to trap the call 361 and analyze the one or more data packets 362 before the socket 336 passes them to the network stack 342. This priority in loading can be carried out via the library load module 314.

The socket wrapper 337 can provide the aforementioned information 364 (including the socket and application metadata) to the call analyzer module 318, which can use this

information to identify network-abusing applications and do so with increased accuracy since internal traffic is not counted as network traffic. In particular, the call analyzer module 318 can determine a number of bytes in each one of the one or more data packets 362. It can also determine which network interface (e.g., WIFI network interface 354) the one or more data packets 362 are traversing by looking at the source IP address of the socket 336. Recall that this is because the source IP address of the socket 336 is also the IP address of the network interface 352, 354, 356, 358 used to transmit the one or more data packets 362 (e.g., WIFI network interface 354).

The call analyzer module 318 can also use the information 364 to identify the originating application 312a via the process ID and/or user ID associated with the originating application 312a. The socket wrapper 337 has access to the process ID and/or the user ID since it is created in the context of the originating application 312a. In comparison, filters 344 are not created in the context of the originating application and therefore do not have access to the process ID and user ID of the originating application 312a. A database of the OS 331 can be used to lookup a name of the originating application 312a based on the process ID and/or user ID provided to the call analyzer module 318 by the socket wrapper 337. The call analyzer module 318 can distinguish internal versus external traffic based on the family or type (or style) of socket 336, which, in one embodiment, can be extracted from metadata of the socket 336. With this information, the call analyzer module 318, can determine if the originating application 312a is generating high network traffic loads and what networks the originating application 312a is burdening.

Once the call 361 is released from the socket wrapper 337 and reaches the OS 331, the socket 336 establishes communication with the responding device (in TCP) or begins transmitting datagrams (in UDP) to the responding device. The one or more data packets 362 can pass through the network stack 342 of the kernel layer 340, where the network stack 342 provides a software interface between the software stack and the network interfaces 352, 354, 356, 358 in hardware. The network stack 342 can include, but is not limited to, network protocols such as TCP and UDP, an internet protocol (IP) or network layer, and a link layer. The kernel layer 340 also acts as an abstraction layer between the hardware layer 350 and the rest of the software stack.

The one or more data packets 362 can exit the software stack and pass through one of the network interfaces 352, 354, 356, 358 of the hardware layer 350 en route to the responding device. In this particular example, the one or more data packets 362 are traversing the WIFI network interface 354 to reach the responding device, but in other embodiments, the cellular network interface 352, Ethernet network interface 356, or BLUETOOTH network interface 358 could also be traversed. The cellular network interface 352 and WIFI network interface 354 are often used for client-host type communications, while the Ethernet network interface 356 is often used for client-host or peer-to-peer communications. The BLUETOOTH network interface 358 is often used for peer-to-peer communications. However, these types of communications are not limiting, nor do the network interfaces 352, 354, 356, 358 make up an exclusive list of those that can be implemented.

As seen, the call intercept library 338, the socket wrapper 337, and the call analyzer module 318, do not influence the call 361, the socket 336, or the transmission of the one or more data packets 362. In other words, trapping the call 361 and analyzing the information 364 before transmission is performed such that the user experience is not degraded. However, if the call analyzer module 318 identifies a net-

work-abusive application and determines to take action regarding the same, then there are embodiments where various aspects of the software stack may be influenced, shut down, curtailed, or otherwise modified.

While current devices typically do not enable two networks to be used simultaneously (e.g., WIFI and 4G or UMTS and CDMA), products in development do have such functionality. For instance, transmission of a stream of data packets may be distributed between two or more networks (e.g., 3G and 4G cellular networks).

For inbound traffic (e.g., downloads), FIG. 4 illustrates one embodiment of a software stack configured to identify network-abusing applications. Traditionally, one or more inbound data packets 464 destined for a destination application 412a are received at one of a plurality of network interfaces 452, 454, 456, 458 (e.g., the WIFI network interface 454 in the illustrated embodiment), and enter the software stack via a network stack 442. The one or more data packets 464 queue at a socket 436 created by an OS 431, and are read by the destination application 412a in response to a “read” call (not illustrated) made by the destination application 412a and received at the socket 436.

However, here, the first socket 436 functionality is replaced by a custom function in the form of an at least one socket wrapper 437 of a call intercept library 438. When the destination application 412a makes a call 461 to read the first socket 436, the call is trapped by the socket wrapper 437 allowing the socket wrapper 437 to analyze the one or more data packets 464 at the first socket 436 before they are read by the destination application 412a. When finished, the socket wrapper 437 releases the call 461 thus enabling the destination application 412a to read the one or more data packets 464 from the socket 436.

Analyzing the one or more data packets 464 at the socket 436 can include obtaining information related to one or more of the following: (1) a number of bytes per data packet; (2) which of the one or more applications 412a, 412b, . . . , 412n the one or more data packets 462 destined for (via a user ID and/or process ID); (3) which network interface 452, 454, 456, 458 was used to receive the one or more data packets 464 (via the source IP address of the socket 436); and (4) whether the one or more data packets 464 are inbound from a responding device or from another application 412b, . . . 412n internal to the initiating device (via metadata indicating a socket address, type of socket, or socket family) (this situation is discussed further with reference to FIG. 5).

When the one or more inbound data packets 464 are inbound to the socket 436, the OS 431 can switch contexts to that of the destination application 412a, which owns the socket 436—a context that the socket wrapper 437 also runs in. The socket wrapper 437 can trap a call 461 to read the socket 436. Having trapped the call 461, and running in the context of the destination application 412a, the socket wrapper 437 can access metadata of the destination application 412a, which includes a process ID and/or user ID that identify the destination application 412a. In some cases, a database of the OS 431 can be used to lookup a name of the destination application 412a—the application that owns the context in which the socket 436 and socket wrapper 437 operate in—based on the process ID and/or user ID. The filters 444, in contrast, are not created in the context of the destination application 412a and therefore do not have access to the destination application 412a metadata and the included process ID and/or user ID.

The OS 431 assigns a socket descriptor to the socket 436 when the socket 436 is created. The kernel maintains a mapping of the socket descriptor to socket metadata as well as

11

methods enabling the socket wrapper **437** to query the kernel for the socket metadata thus giving the socket wrapper **437** access to information such as the socket descriptor, local and remote IP addresses, and socket family, to name a few.

The at least one socket wrapper **437** can provide this information **466** (including the socket and application metadata) to a call analyzer module **418**, which can identify network-abusing applications and do so with increased accuracy. In particular, the call analyzer module **418** can identify a number of bytes in each one of the one or more data packets **464**. It can also determine which network interface (e.g., WIFI network interface **454**) the one or more data packets **464** are traversing by looking at the destination IP address of the one or more data packets **464**. The destination IP address is the local IP address (generally not publicly routable) that the network (e.g., WIFI) assigned to the network interface (e.g., WIFI network interface **454**) traversed by the one or more data packets **464**. In one embodiment, the call analyzer module **418** can use the source IP address of the one or more data packets **464** to identify the remote device that sent the one or more data packets **464** in case the remote device is blacklisted or otherwise an undesirable source.

Internal versus external traffic can be distinguished based on the socket **436** family or type. For instance, the call analyzer module **418** can extract the socket type from metadata of the socket **436** to determine whether the socket **436** is an endpoint for internal or external communications.

With this information, the call analyzer module **418**, can determine if the destination application **412a** is downloading excessive volumes of data and can determine what networks the destination application **412a** is burdening. As in the case of outbound traffic, the call analyzer module **418** can again ignore internal traffic thus providing more accurate monitoring of network usage on a per application basis.

While FIGS. 3-5 have discussed the situations of inbound and outbound traffic independently, it will be understood that the call analyzer modules **318**, **418** are configured to identify network-abusive applications based on analysis of inbound and outbound traffic.

FIG. 5 illustrates an embodiment of a software stack where one or more data packets are being passed between applications on the same device. Here, a call **561** is made to an OS **531**. Before a function of the core libraries **532** for creating a first socket **536** can run, a call intercept library **538** creates a socket wrapper **537** that traps the call **561** and analyzes the call **561** before the one or more data packets are passed to a second socket **535**. In one embodiment, this occurs because a library load module **514** loads the call intercept library **538** before loading the core libraries **537**. The socket wrapper **537** can extract information describing the following from the one or more data packets **564**: (1) a number of bytes per data packet; (2) which of the one or more applications **512a**, **512b**, . . . , **512n** is the source of the one or more data packets **564** (via a user ID and/or process ID); (3) whether the one or more data packets **564** are destined for a responding device or another application **512b**, . . . , **512n** internal to the initiating device (via socket metadata indicating a type of socket address, type of socket, or socket family). This functionality of the socket wrapper **537** is an extension of the core libraries' **532** functionality that replaces the functionality of the first socket **536** with that of the call intercept library **538**.

The socket wrapper **537** can provide this information **566** to a call analyzer module **518**, which can determine that the one or more data packets **564** are not relevant to identifying network-abusive applications since the one or more data packets **564** are internally-directed. In particular, the call analyzer module **518** can determine from the type of socket

12

address, type of socket, or socket family that the one or more data packets **564** are destined for another application of the initiating device or another socket (e.g., second socket **535**) of the initiating device rather than a responding device, and therefore these one or more data packets **564** can be ignored when counting bytes for identification of network-abusing applications.

Once the socket wrapper **537** has trapped the call **561** and extracted the above-noted information, the call **561** is allowed to reach the OS **531**, and the call **561** creates the first socket **536**. The first socket **536** then transmits the one or more data packets **564** to the second socket **535** via the filters **544**.

In one embodiment (not illustrated), the one or more data packets **564** can be routed through the socket wrapper **537** en route to the other application **512b** from the second socket **535**. In such an embodiment, the socket wrapper **537** can analyze the data packets **564** before they reach the first socket **536**. This is one way that the socket wrapper **537** can differentiate local versus outbound/inbound traffic and thereby only pass information to the call analyzer module **518** regarding outbound/inbound traffic.

FIG. 6 illustrates a method **600** for identifying network-abusive applications. The method **600** begins with loading a call intercept library **602** such as the call intercept libraries **338** and **438** illustrated in FIGS. 3 and 4 via the library load modules **314** and **414**. While there may be a plurality of core libraries belonging to the OS, the call intercept library can be configured to load before any of the core libraries. In the alternative, a library load module can be configured to load the call intercept library before any of the core libraries. A socket wrapper, such as socket wrappers **337** and **437** in FIGS. 3 and 4, can then be called **604** by way of functions of the call intercept library. A socket can also be called **606** by way of functions of the at least one of the core libraries (e.g., sockets **336** and **436** in FIGS. 3 and 4). At least one data packet can be received from a remote (responding) application or device **608**. Once received, the destination application (e.g., **412a**) may make a call (e.g., **464**) to the socket to read the data packet (e.g., **464**). This call can be trapped by the socket wrapper **610** and information about the transmission garnered from metadata of the socket and metadata of the destination application.

A number of bytes in the data packet can be extracted **612** while the network interface (e.g., **454**) through which the data packet arrived can also be identified **614**. The destination application can be identified **616** as well as identification as to whether the data packet is external or internal traffic (originating from another application within the same device such as is illustrated in FIG. 5) **618**. With the number of bytes from the data packet, and optionally other information extracted from the data packet and the socket, a network-abusing application can be identified **620**. Once such identification has taken place, or at the same time, or even before the identification but after the trapping of the call **610**, the socket wrapper can release the call **622** so that the destination application can read the data packet.

Identifying the network interface through which the at least one data packet traveled **614** can involve identification via an IP address in metadata of the socket. Identifying the destination application **616** can look at metadata associated with the destination application in whose context the socket wrapper runs. This metadata may include a process ID or user ID that can be mapped to the destination application. Access to this metadata is only available to operations at the OS level (e.g., the socket wrapper **437** in FIG. 4), and in particular to those operations running in the context of the destination application. Such access is unique to operations running at the OS

13

level for incoming data packets, and thus the identify operation **614** cannot be performed by filters operating at the kernel level (e.g., filters **444**). Furthermore, the socket wrapper can look at a type or family of the socket as recorded in metadata of the socket to determine whether the data packet is part of internal or external traffic **618**.

Data extracted from the one or more data packets can be passed to a call analyzer module (e.g., **418**) for analysis and identification of network-abusive applications **620**. The number of bytes, the network interface through which the data packet traveled (or an IP address corresponding to the network interface), the destination application (or a process ID corresponding to the destination application), and the type or family of the socket, can all be passed to the call analyzer module in support of the identification **620**.

FIG. 7 illustrates a method **700** for identifying network-abusive applications. The method **700** begins with loading a call intercept library **702**. While there may be a plurality of core libraries belonging to the OS, the call intercept library can be configured to load before any of the core libraries, or a library load module can be configured to load the call intercept library before it loads any of the core libraries. A socket wrapper, such as socket wrapper **337** in FIG. 3, can then be called **704** by way of functions of the call intercept library. A socket can also be called **706** by way of functions of the at least one of the core libraries. At least one data packet can be received from an originating application **708** (e.g., originating application **312a**) and the originating application can make a call to transmit the data packet. This call can be trapped by the socket wrapper **710** and information about the transmission garnered from metadata of the socket and metadata of the destination application.

A number of bytes in the data packet can be extracted **712** while the network interface (e.g., **354**) through which the data packet arrived can also be identified **714**. The originating application can be identified **716** as well as identification as to whether the data packet is external or internal traffic (destined for another application within the same device such as is illustrated in FIG. 5) **718**. With the number of bytes from the data packet, and optionally other information extracted from the data packet and the socket, a network-abusing application can be identified **720**. Once such identification has taken place, or at the same time, or even before the identification but after the trapping of the call **710**, the socket wrapper can release the call **722** so that the data packet can be transmitted.

Identifying the network interface through which the at least one data packet will travel **714** can involve identification via an IP address in metadata of the socket. Identifying the originating application **716** can look at metadata associated with the originating application in whose context the socket wrapper runs. This metadata may include a process ID or user ID that can be mapped to the originating application. Access to this metadata is only available to operations at the OS level, and in particular to those operations running in the context of the originating application. Such access is unique to operations running at the OS level for incoming data packets, and thus the identify operation **714** cannot be performed by the filters operating at the kernel level for incoming data packets. Furthermore, the socket wrapper can look at a type of family of the socket as recorded in metadata of the socket to determine whether the one or more data packets are part of internal or external traffic **718**.

The order of operations illustrated in FIGS. 6 and 7 are illustrative only and not intended to limit the scope of various orders of operations that are envisioned. For instance, the

14

identification of network-abusive applications **620** and **720** can be carried out before, after, or in parallel with the release of the call **622** and **722**.

In any of the above-noted embodiments, once an application has been identified as a network-abusive application a variety of remedies can be carried out. The network-abusive application can have its communications redirected to a different network or split between multiple networks. The network-abusive application's communications can be throttled or limited. In some cases, only downloads or only uploads may be redirected to a different network or be throttled. In some cases, identification of network-abusive applications can be used by developers in order to modify applications to more efficiently or fairly use network bandwidth. These are just a few non-limiting examples of remedies for network-abusive application, and a variety of other remedies are also envisioned.

The systems and methods described herein can be implemented in a machine such as a computer system in addition to the specific physical devices described herein. FIG. 8 shows a diagrammatic representation of one embodiment of a machine in the exemplary form of a computer system **800** within which a set of instructions can execute for causing a device to perform or execute any one or more of the aspects and/or methodologies of the present disclosure. The components in FIG. 8 are examples only and do not limit the scope of use or functionality of any hardware, software, embedded logic component, or a combination of two or more such components implementing particular embodiments. Exemplary computer systems **800** include, but are not limited to, desktop computers, laptop computers, netbooks, ultrabooks, PDAs, tablet computers, smartphones, media phones, and cellular phones.

Computer system **800** may include a processor **801**, a memory **803**, and a storage **808** that communicate with each other, and with other components, via a bus **840**. The processor **801** may implement the functionality described in the methods of FIGS. 6-7. The processor **801** may also implement the functionality of the following applications: **312a**, **312b**, . . . , **312n**; **412a**, **412b**, . . . , **412n**; and **512a**, **512b**, . . . , **512n**. The processor **801** may also implement the functionality of the call intercept libraries **338**, **438**, **538**, and the socket wrappers **337**, **437**, **537**. Furthermore, the functionality of the call analyzer module **318** can be embodied by the processor **801**. The memory **803** or the storage **808** can store information that the socket wrappers **337**, **437**, **537** extract from the sockets **336**, **436**, **536** or from the one or more outbound data packets **362**, inbound data packets **464**, or data packets **564** that are routed to other applications within the device. Data describing the applications that the call analyzer modules **318**, **418**, **518** identify as network-abusing applications can also be stored in the memory **803** and/or storage **808**. As another example, the call intercept library and the plurality of core libraries can be stored in the memory **803** and/or storage **808**.

The bus **840** may also link a display **832**, one or more input devices **833** (which may, for example, include a keypad, a keyboard, a mouse, a stylus, etc.), one or more output devices **834**, one or more storage devices **835**, and various tangible storage media **836**. All of these elements may interface directly or via one or more interfaces or adaptors to the bus **840**. For instance, the various tangible storage media **836** can interface with the bus **840** via storage medium interface **826**. In some embodiments, the tangible storage media **836** can embody and implement the methods described with reference to FIGS. 3-7.

15

The computer system **800** may have any suitable physical form, including but not limited to one or more integrated circuits (ICs), printed circuit boards (PCBs), mobile handheld devices (such as mobile telephones or PDAs), laptop or notebook computers, distributed computer systems, computing grids, or servers. For instance, examples of the computer system **800** include, but are not limited to, computer systems implementing the software stacks and hardware layers **350**, **450**, **550** illustrated in FIGS. 3-5. The initiating devices and receiving devices herein disclosed are further examples of the computer system **800**.

Processor(s) **801** (or central processing unit(s) (CPU(s))) optionally contains a cache memory unit **802** for temporary local storage of instructions, data, or computer addresses. In one case, the processor(s) **801** can store in cache **802** a destination address of outbound data packets including a destination IP address and a destination port. Processor(s) **801** are configured to assist in execution of computer readable instructions. Computer system **800** may provide functionality as a result of the processor(s) **801** executing software embodied in one or more tangible computer-readable storage media, such as memory **803**, storage **808**, storage devices **835**, and/or tangible storage media **836**. The tangible computer-readable media may store software that implements particular embodiments, and processor(s) **801** may execute the software. In some embodiments, this software may carry out the functionality of the call intercept libraries **338**, **438**, **538** or that of the call analyzer modules **318**, **418**, **518**. Memory **803** may read the software from one or more other computer-readable media (such as mass storage device(s) **835**, **836**) or from one or more other sources through a suitable interface, such as network interface **820**. The network interface **820** may take the form of any of the various network interfaces described with reference to FIGS. 3-5 (e.g., a WIFI network interface **354**). The software may cause processor(s) **801** to carry out one or more processes or one or more steps of one or more processes described or illustrated herein. Carrying out such processes or steps may include defining data structures stored in memory **803** and modifying the data structures as directed by the software.

The memory **803** may include various components (e.g., machine readable media) including, but not limited to, a random access memory component (e.g., RAM **804**) (e.g., a static RAM "SRAM", a dynamic RAM "DRAM, etc.), a read-only component (e.g., ROM **805**), and any combinations thereof. ROM **805** may act to communicate data and instructions unidirectionally to processor(s) **801**, and RAM **804** may act to communicate data and instructions bidirectionally with processor(s) **801**. ROM **805** and RAM **804** may include any suitable tangible computer-readable media described below. In one example, a basic input/output system **806** (BIOS), including basic routines that help to transfer information between elements within computer system **800**, such as during start-up, may be stored in the memory **803**.

Fixed storage **808** is connected bidirectionally to processor(s) **801**, optionally through storage control unit **807**. Fixed storage **808** provides additional data storage capacity and may also include any suitable tangible computer-readable media described herein. Storage **808** may be used to store operating system **809**, EXECs **810** (executables), data **811**, APV applications **812** (application programs), and the like. EXECs **810** and/or the APV applications **812** can be embodied by any one or more of applications **312a**, **312b**, . . . , **312n**; **412a**, **412b**, . . . , **412n**; and **512a**, **512b**, . . . , **512n**. Often, although not always, storage **808** is a secondary storage medium (such as a hard disk) that is slower than primary storage (e.g., memory **803**). Storage **808** can also include an

16

optical disk drive, a solid-state memory device (e.g., flash-based systems), or a combination of any of the above. Information in storage **808** may, in appropriate cases, be incorporated as virtual memory in memory **803**.

In one example, storage device(s) **835** may be removably interfaced with computer system **800** (e.g., via an external port connector (not shown)) via a storage device interface **825**. Particularly, storage device(s) **835** and an associated machine-readable medium may provide nonvolatile and/or volatile storage of machine-readable instructions, data structures, program modules, and/or other data for the computer system **800**. In one example, software may reside, completely or partially, within a machine-readable medium on storage device(s) **835**. In another example, software may reside, completely or partially, within processor(s) **801**.

Bus **840** connects a wide variety of subsystems. Herein, reference to a bus may encompass one or more digital signal lines serving a common function, where appropriate. Bus **840** may be any of several types of bus structures including, but not limited to, a memory bus, a memory controller, a peripheral bus, a local bus, and any combinations thereof, using any of a variety of bus architectures. As an example and not by way of limitation, such architectures include an Industry Standard Architecture (ISA) bus, an Enhanced ISA (EISA) bus, a Micro Channel Architecture (MCA) bus, a Video Electronics Standards Association local bus (VLB), a Peripheral Component Interconnect (PCI) bus, a PCI-Express (PCI-X) bus, an Accelerated Graphics Port (AGP) bus, HyperTransport (HTX) bus, serial advanced technology attachment (SATA) bus, and any combinations thereof.

Computer system **800** may also include an input device **833**. In one example, a user of computer system **800** may enter commands and/or other information into computer system **800** via input device(s) **833**. For instance, a user may input a domain name or GOOGLE search into an input device **833** such as a keyboard. Alternatively, a web search may be performed via voice commands using an input device **833** such as a microphone. Examples of an input device(s) **833** include, but are not limited to, an alpha-numeric input device (e.g., a keyboard), a pointing device (e.g., a mouse or touchpad), a touchpad, a joystick, a gamepad, an audio input device (e.g., a microphone, a voice response system, etc.), an optical scanner, a video or still image capture device (e.g., a camera), and any combinations thereof. Input device(s) **833** may be interfaced to bus **840** via any of a variety of input interfaces **823** (e.g., input interface **823**) including, but not limited to, serial, parallel, game port, USB, FIREWIRE, THUNDERBOLT, or any combination of the above.

In particular embodiments, when computer system **800** is connected to network **830**, computer system **800** may communicate with other devices, specifically mobile devices and enterprise systems, connected to network **830**. For instance, an initiating device and a responding device can communicate via the network **830**. Communications to and from computer system **800** may be sent through network interface **820** (e.g., network interfaces **352**, **354**, **356**, **358**, **452**, **454**, **456**, **458**, **552**, **554**, **556**, **558**). For example, network interface **820** may receive incoming communications (such as requests or responses from a responding device) in the form of one or more data packets (such as Internet Protocol (IP) packets) from network **830**, and computer system **800** may store the incoming communications in memory **803** for processing. Computer system **800** may similarly store outgoing communications (such as requests or responses to other devices) in the form of one or more data packets in memory **803** and communicated to network **830** from network interface **820**. Processor(s) **801** may access these communication packets

17

stored in memory **803** for processing. For instance, the processor(s) **801** may analyze outbound data packets to identify a network interface that is to be traversed by the outbound data packets.

Examples of the network interface **820** include, but are not limited to, a network interface card, a modem, and any combination thereof. Examples of a network **830** or network segment **830** include, but are not limited to, a wide area network (WAN) (e.g., the Internet, an enterprise network), a local area network (LAN) (e.g., a network associated with an office, a building, a campus or other relatively small geographic space), a telephone network, a direct connection between two computing devices, and any combinations thereof. A network, such as network **830**, may employ a wired and/or a wireless mode of communication including WIFI and cellular networks. In general, any network topology may be used.

Information and data can be displayed through a display **832**. Examples of a display **832** include, but are not limited to, a liquid crystal display (LCD), an organic liquid crystal display (OLED), a cathode ray tube (CRT), a plasma display, and any combinations thereof. The display **832** can interface to the processor(s) **801**, memory **803**, and fixed storage **808**, as well as other devices, such as input device(s) **833**, via the bus **840**. The display **832** is linked to the bus **840** via a video interface **822**, and transport of data between the display **832** and the bus **840** can be controlled via the graphics control **821**. The display **832** can present rendered graphics and text generated by the one or more applications **312a**, **312b**, . . . , **312n**; **412a**, **412b**, . . . , **412n**; and **512a**, **512b**, . . . , **512n**.

In addition to a display **832**, computer system **800** may include one or more other peripheral output devices **834** including, but not limited to, an audio speaker, a printer, and any combinations thereof. Such peripheral output devices may be connected to the bus **840** via an output interface **824**. Examples of an output interface **824** include, but are not limited to, a serial port, a parallel connection, a USB port, a FIREWIRE port, a THUNDERBOLT port, and any combinations thereof.

In addition or as an alternative, computer system **800** may provide functionality as a result of logic hardwired or otherwise embodied in a circuit, which may operate in place of or together with software to execute one or more processes or one or more steps of one or more processes described or illustrated herein. Reference to software in this disclosure may encompass logic, and reference to logic may encompass software. Moreover, reference to a computer-readable medium may encompass a circuit (such as an IC) storing software for execution, a circuit embodying logic for execution, or both, where appropriate. The present disclosure encompasses any suitable combination of hardware, software, firmware, or a combination thereof.

Those of skill in the art will understand that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

Those of skill in the art will further appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, firmware or combinations of these. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, mod-

18

ules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware, software, or firmware depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention.

The various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

The steps of a method or algorithm described in connection with the embodiments disclosed herein (e.g., FIGS. 6 and 7) may be embodied directly in hardware, in a software module executed by a processor, in a firmware module executed by a processor, or in a combination of these. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal. In the alternative, the processor and the storage medium may reside as discrete components in a user terminal.

The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. A communication apparatus for monitoring applications, the communication apparatus comprising:
 - a network interface configured to receive a data packet from a network;
 - a memory for storing:
 - a plurality of core libraries; and
 - a call intercept library;
 - a processor for running:
 - a library load module configured to load the call intercept library and any of the plurality of core libraries, the call intercept library loaded before any of the plurality of core libraries that were loaded;
 - an application configured to read and process the data packet;

19

a socket based in one of the plurality of core libraries, configured to be called by the application using functionality of one of the plurality of core libraries after the network interface receives the data packet, and to receive the data packet from the network interface;

a socket wrapper based in the call intercept library, configured to

trap a call from the application to the socket in order to read the data packet,

ascertain a number of bytes in the data packet, and release the call to the socket so that the application can read the data packet; and

a call analyzer module configured to determine a network traffic load attributable to the application based at least on the number of bytes in the data packet.

2. The communication apparatus of claim 1, wherein the call analyzer module identifies the network interface through which the data packet arrived.

3. The communication apparatus of claim 2, wherein the socket wrapper extracts an IP address from the data packet and passes the IP address to the call analyzer module, where the call analyzer module uses the IP address to identify the network interface through which the data packet arrived.

4. The communication apparatus of claim 1, wherein the call analyzer module determines whether the data packet originated internally or externally to the communication apparatus.

5. The communication apparatus of claim 4, wherein the socket wrapper is configured to access a type or family of the socket and provide this type or family to the call analyzer module, wherein the call analyzer module uses the type or family of the socket to determine whether the data packet originated internally or externally to the communication apparatus.

6. The communication apparatus of claim 1, wherein the call analyzer module is configured to identify the destination application.

7. The communication apparatus of claim 6, wherein the destination application is identified from a process ID extracted from metadata associated with the application.

8. The communication apparatus of claim 7, wherein the socket wrapper runs in the context of the application.

9. The communication apparatus of claim 8, wherein the socket runs in the context of the application.

10. The communication apparatus of claim 7, further comprising mapping the process ID to the destination application via a mapping that is only available at the OS layer.

11. The communication apparatus of claim 1, wherein the call analyzer module is further configured to identify the application as a network-abusing application if the network traffic load exceeds a threshold.

12. A method of monitoring network-abusing applications via methods at an operating system (OS) layer of a communications device, the method comprising:

loading a call intercept library prior to loading any core libraries of the OS;

calling a socket wrapper by way of functions of the call intercept library;

calling a socket by way of functions of at least one of the core libraries;

20

receiving at least one data packet, from a responding application external to the communications device, at the socket;

trapping a call, from a destination application of the communications device, to read the at least one data packet; counting a number of bytes from the at least one data packet; and

releasing the call to the socket so that the at least one data packet is read by the destination application.

13. The method of claim 12, further comprising identifying a network interface through which the at least one data packet traveled.

14. The method of claim 13, wherein the network interface is identified via an IP address in metadata of the at least one data packet.

15. The method of claim 12, further comprising determining whether the at least one data packet originated internally or externally to the communications device.

16. The method of claim 15, wherein the determining looks at a type or family of the socket.

17. The method of claim 12, further comprising identifying the destination application from metadata associated with the destination application.

18. The method of claim 17, wherein the socket wrapper operates in a context of the destination application.

19. The method of claim 17, wherein the destination application is identified from a process ID extracted from metadata associated with the destination application.

20. The method of claim 19, further comprising mapping the process ID to the destination application via a mapping that is only available at the OS layer.

21. A non-transitory, tangible computer readable storage medium, encoded with processor readable instructions to perform a method for identifying network-abusing applications on a communication apparatus, the method comprising:

loading a call intercept library prior to loading any core libraries of an operating system (OS) of the communication apparatus;

calling a socket wrapper by way of functions of the call intercept library;

calling a socket by way of functions of at least one of the core libraries;

trapping a call, from an originating application, to transmit at least one data packet;

counting a number of bytes from the at least one data packet; and

releasing the call to the socket so as to allow the socket to release the at least one data packet for transmission.

22. The non-transitory, tangible computer readable storage medium of claim 21, further comprising, passing the number of bytes to a call analyzer module configured to compare the number of bytes to a threshold and to identify network-abusive applications.

23. The non-transitory, tangible computer readable storage medium of claim 22, wherein to compare the number of bytes to a threshold involves comparing a cumulative number of bytes received by the call analyzer module and associated with the originating application.

* * * * *